U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB-285 434

Evaporative Recovery of Chromium Plating Rinse Waters

Advance Plating Co, Cleveland, Ohio

Prepared for

Industrial Environmental Research Lab -Cincinnati, Ohio

Jun 78

United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Cincinnati OH 45268

EPA-600/2-78-127
June 1978

Research and Development

PB 285 434

EPA

Evaporative Recovery of Chromium Plating Rinse Waters

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TECHNICAL REPORT DATA
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1. REPORT NO. EPA-600/2-78-127	2.
3. RECIPIENT'S ACCESSION NO. PB285434	
4. TITLE AND SUBTITLE: Evaporative Recovery of Chromium Plating Rinse Waters	5. REPORT DATE: June 1978 issuing date
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S): Leonard N. Elicker, Advance Plating Company; Roger W. Lacy, Corning Glass Works, Corning, N.Y.	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Advance Plating Company, Cleveland, Ohio 44103	10. PROGRAM ELEMENT NO. 1BB610
	11. CONTRACT/GRANT NO. S803781
12. SPONSORING AGENCY NAME AND ADDRESS: Industrial Environmental Research Lab., Cinn, OH; Office of Research and Development; U.S. Environmental Protection Agency; Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED: Final
	14. SPONSORING AGENCY CODE: EPA/600/12
15. SUPPLEMENTARY NOTES	

16. ABSTRACT This demonstration project documents the practicality of a new evaporative approach for recovering chromic acid from metal finishing rinse waste waters, as well as the economics of the system under actual operating conditions.

The six-month study of chrome plating operations was conducted by Advance Plating Company in Cleveland, Ohio. The design of the recovery system centered around a Corning PCR-60 climbing-film evaporative recovery unit manufactured by Corning Glass Works, a cation exchange column and monitoring equipment.

The test design established a preliminary data base from information collection prior to system operation. Histories of chemical use were also compiled to aid in the cost analysis.

The active study program involved collecting and evaluating data to determine the economics of the recovery approach as well as investigating the effects of varying rinse flow rates economics and rinsing quality. Results of the study showed that the system can be accommodated with little impact on the existing operation. The recovered chromic acid can be recycled back into the bath without affecting product quality. The recovery system can decrease chromic acid consumption significantly and is economically viable.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Evaporation Chromic acid Materials Recovery Waste water Electroplating	Chrome Plating line Vacuum, climbing-film evaporator	68D

18. DISTRIBUTION STATEMENT: Release to public	19. SECURITY CLASS *(This Report)*: Unclassified	21. NO. OF PAGES: 52
	20. SECURITY CLASS *(This page)*: Unclassified	22. PRICE: A04 - A01

EPA Form 2220-1 (9-73)

* U.S. GOVERNMENT PRINTING OFFICE 1978—757-140/1359

EPA-600/2-78-127
June 1978

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FOREWORD

When energy and material resources are extracted, processed, converted, and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory - Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

This report is a product of the above efforts. These studies were undertaken to describe the methodology and determine the economics of a new evaporative approach for recovering chemicals from metal finishing rinse waters. The testing was performed in a typical chrome plating job shop. This evaporative recovery method combines simplicity and ease of operation with the capabilities to effectively reduce chromic acid consumption.

Such information will be of value both to EPA's regulatory program (Effluent Guidelines Division) and to the industry itself in arriving at meaningful and achievable discharge levels. Within EPA's R & D program the information will be used as part of the continuing program to develop and evaluate improved and less costly technology to minimize industrial waste discharges. Besides its direct application to effluents from metal finishing industry, this technology may find application to treat metal-containing wastes generated by a host of other industries.

For further information concerning this subject the Industrial Pollution Control Division should be contacted.

David G. Stephan
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ABSTRACT

This demonstration project was initiated to document the practicality of a new evaporative approach for recovering chromic acid from metal finishing rinse waste waters, as well as to determine the economics of the system under actual operating conditions in a typical job shop. An additional objective involved verification of the theoretical equations relating to countercurrent rinsing used in system sizing and design.

The six-month study of chrome plating operations was conducted by Advance Plating Company, a large job shop in Cleveland, Ohio. The plating line was a Udylite sidearm 350 two-lane machine utilizing a Udylite K-40 proprietary chromic acid solution. The design of the recovery system centered around a Corning PCR-60 vacuum climbing-film evaporative recovery unit manufactured by Corning Glass Works. An Industrial Filter cation exchange column was installed to remove contaminants from the rinse waters prior to concentration.

The active study program involved collecting and evaluating operating and maintenance data to determine the economics of the recovery approach as well as to investigate the effects of varying rinse flow rates on recovery economics and rinsing quality. The data obtained on the effects of varying the rinse flow rate were used to study the relationship between theoretical mathematical formulas and actual counterflow system performance.

Results of the study showed that the recovery system can be accommodated by an electroplating job shop with little impact on the existing operation. The recovered chromic acid can be successfully recycled back into the plating bath without affecting product quality. The recovery system can decrease chromic acid consumption significantly and is economically viable, particularly when chemical destruction is being practiced. The study also confirmed the accuracy of theoretical equations for system sizing and design.

This report is submitted in fulfillment of Grant No. S-803781 by Advance Plating Company under the (partial) sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 1, 1976 to September 30, 1976, and work was completed as of August 15, 1976.

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SECTION 1

INTRODUCTION

Presently, the commonly used procedure for treating metal finishing waste waters involves separation of oil and grease, oxidative destruction of cyanides, reduction of chromates, neutralization, separation of the metal hydroxides and disposal of the sludge. However, the quality of the treated effluents is generally not suitable for recycling and the precipitated heavy metal sludges present a potential pollution problem when disposed of on land. As a result of these limitations and the Federal legislative goal of no discharge of pollutants, there has been significant emphasis on developing, demonstrating and expanding the application of process technology for recovering metals from metal finishing waste waters, as well as sludges.

Recent years have seen a rapidly expanding collection of knowledge and experience in chemical recovery efforts within the metal finishing industry. This growing technology, both in well-established processes and the development of new processes, now offers metal finishers many options in equipment selection. As a result, metal finishers now need more information concerning the economics and performance of the variety of recovery systems available.

Among the more attractive approaches for recovering chemicals from metal finishing waste waters are evaporation, ion exchange, reverse osmosis, electrodialysis, and electrolytic techniques.

The present study focuses on providing more comprehensive performance and economic information on a new evaporative approach for recovering chemicals and purifying chromic acid rinse waters for reuse.

SECTION 2

CONCLUSIONS

A full-scale climbing film evaporative recovery system with associated equipment can be successfully integrated into an electroplating "job shop" with minimum impact on the existing operation and without additional manpower.

Under typical plating shop conditions, the consumption of chromic acid can decrease 80% with a minimum of equipment supervision. Recovery can reduce the chromic acid in the effluent from dragout by 99.98%.

The concentration and purity of the recovered chromic acids, when accompanied by good housekeeping practices, is adequate for recycling back into the plating bath without affecting product quality.

The installed cost of the equipment is sufficiently low that equipment payback may be two years or less.

Engineering equations and nomographs currently used to predict rinse tank concentrations under different conditions can be used accurately for 1, 2, or 3 rinse tanks at low rinse ratios.

SECTION 3

RECOMMENDATIONS

This full-scale inplant study demonstrated the economic validity of an evaporative recovery system for waste waters. The project also showed that the effluent from plating rinse dragout can be virtually eliminated.

It is recommended that the preferred technology for chromium electroplating pollution abatement be structured around recovery systems as opposed to neutralization and sludge generating systems that translate a water pollution problem into a landfill pollution problem. Recovery will significantly reduce pollutants by internal process recycle and offer savings from the elimination of neutralization chemicals.

Though this study was concerned only with decorative chromium operations, other electroplating solutions are currently being recycled successfully. It is recommended that the Environmental Protection Agency document those systems operating successfully and initiate efforts to study shop impact and recovery economics for the remainder.

SECTION 4

MATERIALS AND METHODS

SITE DESCRIPTION

The site selected for the demonstration project was Advance Plating Company, Cleveland, Ohio. The plating line involved was a Udylite Sidearm 350 two-lane machine with several cleaning stations, a copper strike tank, a copper plate tank, three nickel plating tanks, and a chrome plating tank, all with appropriate rinses. This report concerns only the chrome plating operation.

Advance Plating processes 20,000 to 25,000 racks per month through this line which averages 20 hours of operation a day, five days a week. The machine processes automotive parts, appliance components, and plumbing fixtures. Though most of the parts are zinc diecast, containing a small percentage of aluminum, some are brass and steel.

The chromic acid used is a Udylite K-40 proprietary solution which contains Type 107 fluoride catalyst and MSP-2 wetting agent for mist control and dragout reduction. Barium carbonate is added as required to maintain the proper sulphate level.

The company's chrome consumption for this line in 1975 is shown in Table 1 and in Fig. 1. It ranged from 225 kg (496 lb) to 420 kg (926 lb) per month.

INSTALLATION DESCRIPTION

The layout of the chrome plating line and recovery loop evaluated in this project is shown schematically in Fig. 2. The system has four rinse tanks. The first three are in a counterflow configuration. The fourth is a still rinse.

The first and second rinses are air-agitated. Water in the third rinse, which also has a spray system, is kept circulating in the tank by a pump. The fourth tank is emptied and refilled with fresh water daily, and is maintained at 130^{o}F to facilitate drying.

TABLE 1. 1975 CHROME CONSUMPTION-ADVANCE PLATING

Month	Days of Operation	Chrome Consumption kg	(lb)	Number of Racks Plated	Chrome Consumption Per Rack g	(lb)
Jan.	22	225	(496)	10,329	21.8	(0.048)
Feb.	20	300	(662)	13,230	22.7	(0.050)
Mar.	20	329	(725)	14,373	22.9	(0.051)
Apr.	22	420	(926)	16,443	25.5	(0.056)
May	21	314	(693)	14,987	20.9	(0.046)
June	20	300	(662)	17,587	17.1	(0.038)
July	18	240	(529)	11,729	20.5	(0.045)
Aug.	21	240	(529)	11,861	20.2	(0.045)
Sept.	-	254	(560)	-	-	
Oct.	-	360	(794)	-	-	
Nov.	-	269	(593)	-	-	
Dec.	-	284	(626)	-	-	

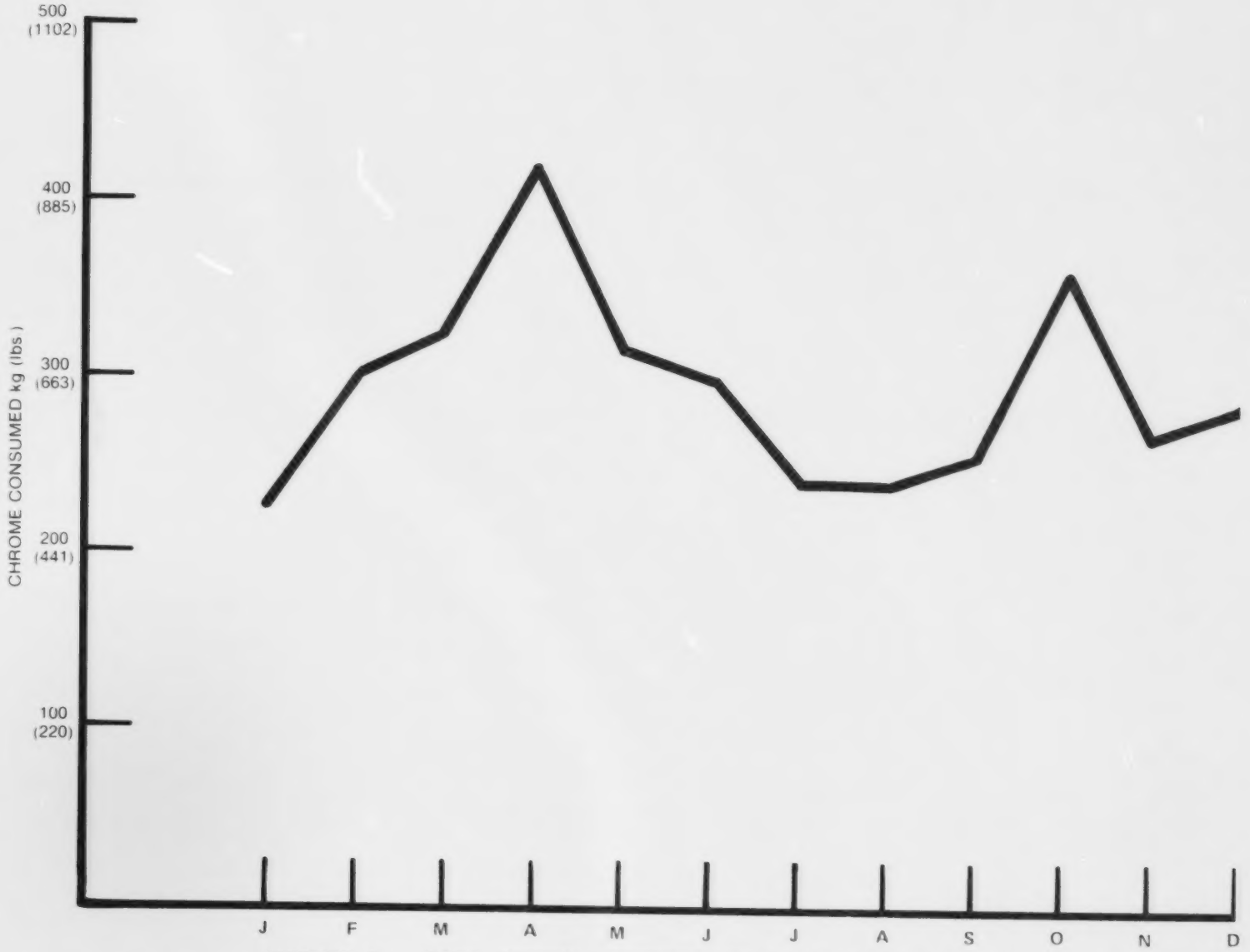

FIGURE 1. 1975 CHROME CONSUMPTION AT ADVANCE PLATING

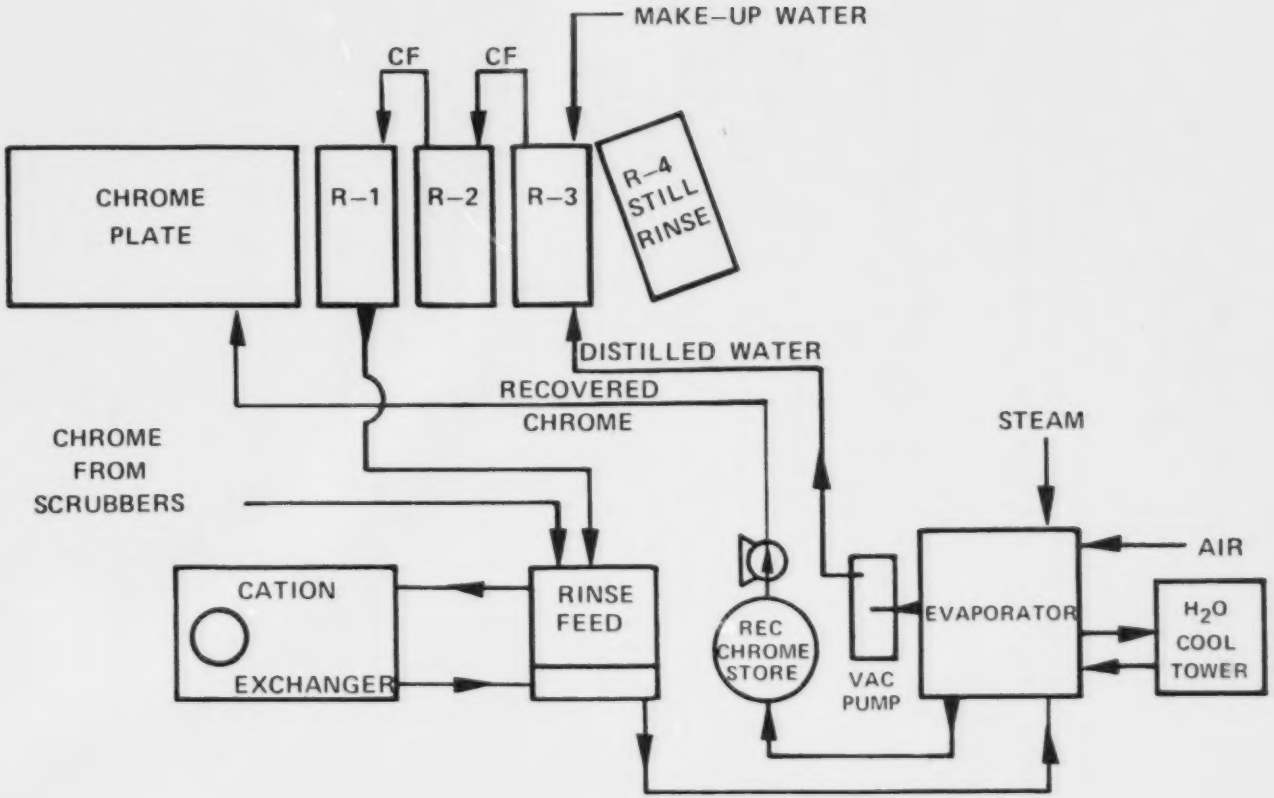

FIGURE 2. ADVANCE PLATING RECOVERY SYSTEM LAYOUT

Rinse water containing the dragged-out chrome plating solution flows from the first rinse tank to a two-chambered rinse feed tank. This two-chamber configuration was used for flow measurements, and is discussed later.

The dilute chrome rinse is pumped from one rinse feed tank chamber into an Industrial Filter rubber-lined cation exchanger to prevent the buildup of metallic impurities. This column contains eight cubic feet of Dow Chemical MSC-1 resins. From the cation exchanger, the rinse water flows to the second rinse feed tank chamber. Rinse water is then drawn from this "clean" side into the evaporator by system vacuum on demand from the evaporator level control.

EVAPORATOR DESCRIPTION

The evaporator employed was a Corning PCR-60 plating chemical recovery unit manufactured by Corning Glass Works. Fig. 3 shows the unit installed at Advance Plating.

Dilute rinse entering the evaporator mixes with solution already in the unit. Water is boiled off by the steam-heated boiler with vertical tubes -- a climbing film evaporator. The water vapor and concentrated solution enter the separator chamber where the concentrated acid drops into the recirculatory loop and the water vapor exits through the mist pad into the condenser. Condensed water is removed from the system by a liquid ring vacuum pump, and is returned to the third rinse tank in the counter-flow rinse system.

The recovered acid remains in the system while additional water is boiled off. An automatic controller senses when the recovered acid reaches a pre-set concentration and initiates a drain cycle. At Advance Plating, this concentration was 65 ounces per gallon. The evaporator then drains 20 gallons of recovered concentrated acid into a product storage tank. This drain cycle takes four minutes and occurs usually once in 16 operating hours.

Services to the unit are steam, maintained between 1 and 6 psig, cooling water at flow rates up to 50 gallons per minute, and vacuum maintained between 9 and 14 inches of mercury.

The Corning plating chemical recovery evaporators are fully automatic and self-alarming. The water balance is controlled by a level controller which admits dilute feed at the same rate at which the evaporator is boiling. The concentration sensor assures the chemical balance of the system whether the parts being plated are flat and have little dragout or

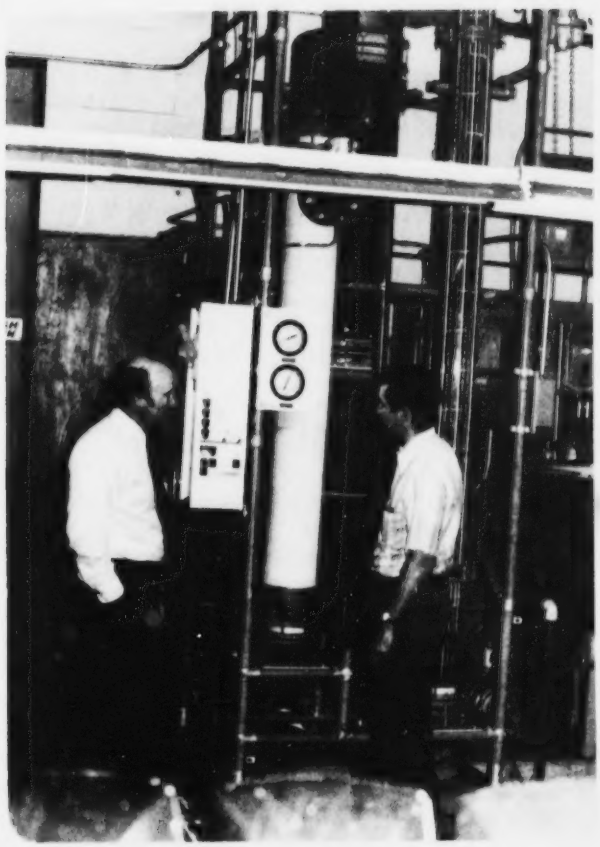

FIGURE 3. RECOVERY SYSTEM AT ADVANCE PLATING

whether they are eschuteons with pockets that create large amounts of dragout. Recovered acid concentrate is preselected according to the needs at hand. The setting of 65 ounces per gallon at Advance Plating assured that the removed volume of concentrate would be accommodated when returned to the plating tank. Other applications have used dumping concentrations as low as 30 ounces per gallon and as high as 160 ounces per gallon.

MONITORING EQUIPMENT

In addition to the evaporator system's standard sensing and control equipment, special monitoring equipment was added in order to obtain additional information demanded by the project's objectives.

A Fisher Governor differential pressure transmitter was installed in parallel with the evaporator's automatic concentration controller. These continuously sensed chrome density within the evaporator. The transmitter supplied a 3- to 15-psig signal proportional to chrome density. This signal was recorded on a Rustrak Model 2162 strip chart recorder.

The recorder ran 24 hours a day, and indicated when the evaporator was started, when concentrated plating solution was removed, when the unit was shut down, and the time intervals between operations. These data (see Fig. 4) enabled us to calculate the total amount of chrome recovered.

Additional special instrumentation monitored the total amount of dilute rinse feed entering the evaporator. This was accomplished using an event recorder that noted the time required for the smaller section of the feed tank to drain. This information indicated the flow rate in gallons per hour. The total steam used was determined by measuring steam condensate flow in a similar manner. The third recorder trace indicated the addition of make-up water to the system.

Calculations using the data from the event recorder were performed in the following manner (refer to Fig. 5):

Rinse Feed Rate

The volume of water in the rinse feed tank is represented by the difference between the highest liquid level (point A, as feed to the measuring chamber is stopped) and the lowest liquid level (point B, as feed to the measuring chamber is started). This was measured to be 166.54 liters (44 gal). The time (from A to B) required to empty the chamber was

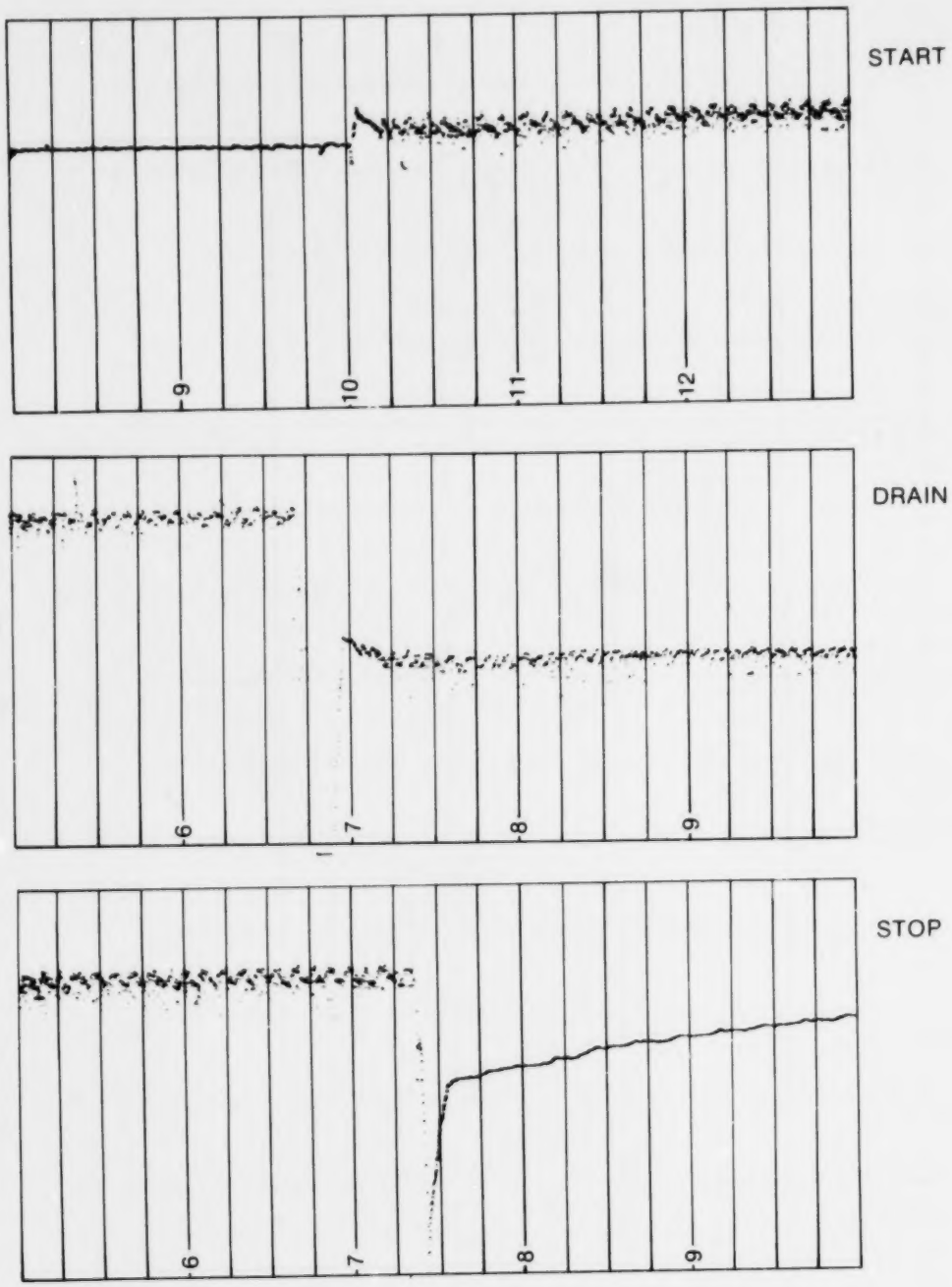

FIGURE 4. RECORDER TRACE SHOWING START, DRAIN AND STOP CYCLES

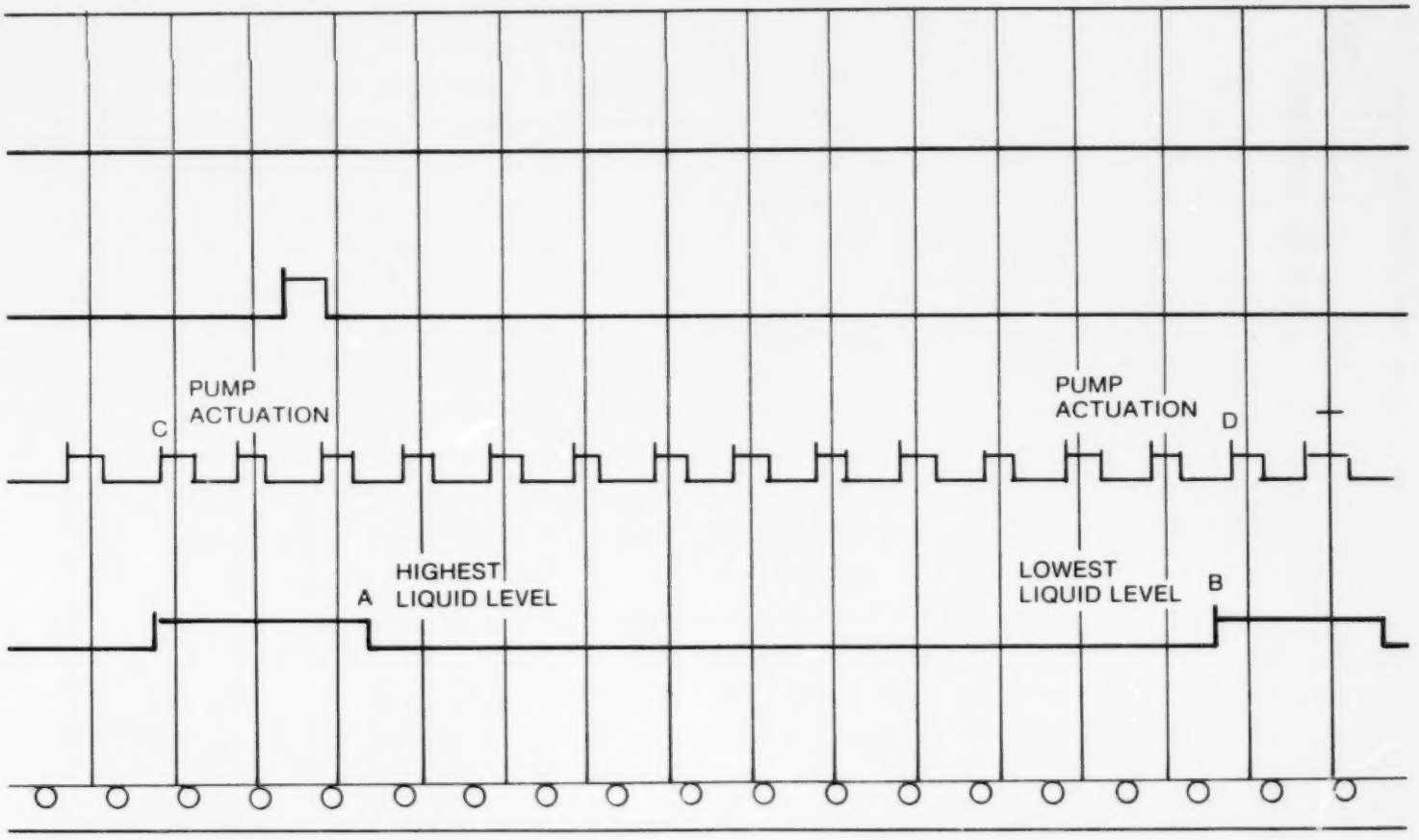

FIGURE 5. SAMPLE EVENT RECORDER TRACE (2X)

determined by measuring the distance between A and B and calculating its time equivalent. The boil-off rate of the evaporator is then:

volume of chamber/time to empty

Steam Condensate Rate

The volume in the chamber of the steam condensate tank was measured to be 6.245 liters (1.65 gal). Multiplying the frequency of the pump actuations (C and D, for example) by the volume provides the steam condensate rate.

TEST PROGRAM

The test program for this project was divided into three investigation areas: Establish a data base; conduct the active study program; collect operating and maintenance cost data. Data for these areas was collected simultaneously.

The Data Base

The data base was established on information gathered before the recovery system became operational. Five aspects were studied and further contributed to the study program and cost analysis:

1. Measurement of trace contaminants in the bath.
2. Measurement of rinse flow rates through the counterflow rinse system.
3. Analysis of chrome concentration in each rinse tank.
4. History of chromic acid additions to the plating bath.
5. History of the production rate (number of racks plated per month).

A sixth measurement recording wetting agent additions was not accomplished due to difficulty in obtaining accurate readings.

A discussion of these variables is given later in comparison to corresponding data obtained during the operation of the recovery system.

The Active Study Program

The scope of the active study program involved determining the effect that varying rinse flow rates had on recovery economics and rinsing quality. These data were used to determine the relationship between the theoretical mathematical formulas used in sizing evaporator equipment and actual counterflow system performance.

Cost Data Collection

The determination of operating costs and recovery efficiency of the evaporative recovery system relied on measurements made prior to operation (the data base) as well as actual operating data. For this purpose, additional information was recorded on variables such as cooling water flow rates, steam and electrical consumption, and rate of return of the product to the plating bath.

SECTION 5

RESULTS AND DISCUSSION

CHROME CONSUMPTION AND DRAGOUT

Key reasons for collecting data on chrome usage prior to the start-up of the recovery system were to determine the plating bath dragout rate and to establish a basis for comparison when looking at recovery economics.

Average dragout rate can be calculated by using the average operating time of 20 hours per day, the number of operating days per month and the chrome consumption for that month. As mentioned earlier, the chrome consumption for Advance Plating in 1975 is presented in Table 1 and Fig. 1. Using these figures, the calculation provides an average chrome usage of 2.73 liters (0.72 gal) of bath per hour. Previous experience has shown that approximately 10% of the chrome used is actually plated on the ware while 90% is dragged out to the rinse waters.

Using that same ratio, a dragout rate of 2.46 liters (0.65 gal) of plating bath per hour can be expected. The average plating bath concentration at the time the data was collected was 300 g/l (40 oz/gal).

In order to verify the magnitude of the dragout rate, a second method of measurement was also used. For this measurement, the first rinse tank was filled with clear tap water. The chrome content in the first rinse was measured hourly for four hours with the following results:

Sample Taken	gm/l CrO_3
Start	0.0022
After 1 hour	0.92
After 2 hours	1.90
After 3 hours	2.77
After 4 hours	3.81

Average increase in concentration per hour was 0.95 g/l or 0.127 oz/gal. The volume of the rinse tank is 1014 liters (268 gal) making the amount of chrome carried into the first

rinse tank 963 gm (34 oz) per hour or 3.1 liters (0.81 g) per hour of dragout. Bath concentration was measured at 312 g/l (42 oz/gal).

The first calculated dragout rate of 2.46 l/hr (0.65 gph) represents an average over an extended period of time. This number may be slightly inaccurate because of changing bath concentrations and the fact that during a working day not all racks of ware are chrome plated.

The second calculation of 3.10 l/hr would be nearer the maximum dragout rate encountered, since it assumes that all plated parts go through the chrome plating tank. The actual figure lies between these two numbers and the use of any dragout rate within these values is accurate for the scope of this evaluation. For analytical purposes in this report, we use 2.84 liters/hour (0.75 gph) at a bath concentration of 300 grams/liter (40 oz/gal).

RINSE TANK PERFORMANCE

The theoretical rinsing equations discussed by Pinkerton and Graham[1] have been shown by Abegg[2] to be in the general form:

$$\frac{Co}{Ci} = \frac{R^{(n+1)}-1}{R^{(n+1)-i}-1} \qquad (1)$$

which, for large values of R, reduces to:

$$\frac{Co}{Ci} = R^{i} \quad , \qquad (2)$$

where C_o = concentration in the plating bath, C_i = concentration in the "i^{th}" rinse tank in the series (i = 0, 1, 2, ... n), n = number of rinse stages in the countercurrent series, and R = rinse ratio defined as rinse flow rate/dragout rate.

[1] A.K. Graham and H.L. Pinkerton, Electroplating Engineering Handbook, Chapter 34, Rinehold Publishing Corp., NY. 1971.

[2] Dr. C. Abegg, "A Practical Simplified Form of the General Countercurrent Rinsing Equation". Corning Glass Works, Corning, NY, internal document.

With this equation, the concentration in any countercurrent rinse position can be calculated. This, of course, assumes perfect rinsing. Pinkerton and Graham state: "Good practice will approach this ideal as closely as possible by incorporating the following features:

1. Vigorous agitation of the rinse water with air.

2. Introduction of fresh water at the bottom of the tank.

3. Placing the overflow weir at the opposite end of the tank from the point at which water is introduced."

Advance Plating incorporates a rinsing system that is probably more typical than perfect. The first recommendation is incorporated in the first two tanks; the second is found in all three tanks, while the third is not used at all.

Samples of the rinse tank waters from each of the three counterflow rinse tanks were taken at regular intervals and analyzed for chrome content (Table 2). Since the dragout rate from the plating bath was calculated and the rinse flow rate was known, the rinse ratio can be calculated. Comparison of the data collected and theoretical curves indicate close agreement between the actual and calculated performances in the first rinse tank (Fig. 6). The curve represents theoretical concentrations based on the actual dragout rate at Advance Plating. The points (from the data in Table 2) are actual concentrations at given rinse rates.

Data on rinse flow rates taken before start-up of the recovery system illustrate the typical use of higher rinsing rates. (The data points at high rinse ratios are shown near the horizontal slope of the curve.) The data plotted below rinse ratio 100 was taken during the active test program and reflect operation at very low rinse ratios typical of such a recovery system.

Similar agreement between actual and theoretical performances for the second and third rinse tanks is shown in Figs. 7 and 8.

From this comparison of actual and theoretical data, the following conclusions and recommendations are drawn:

1. Agreement between theoretical and actual performances for the first, second and third rinse tanks at lower rinse ratios is excellent and tends to verify dragout estimates.

TABLE 2. CHROME CONCENTRATIONS IN FIRST, SECOND AND THIRD COUNTERFLOW RINSE TANKS

Date	First Rinse g/l	First Rinse (oz/gal)	Second Rinse ppm	Third Rinse ppm	Rinse Rate l/hr	Rinse Rate (gph)	Rinse Ratio R
10/3/75	1.08	(0.126)	15.0	4.5	1272	(336)	420
10/10/75	0.75	(0.100)	37.5	-	1090	(288)	360
10/15/75	1.13	(0.150)	-	-	636	(168)	210
10/17/75	1.13	(0.150)	-	-	659	(174)	217
10/22/75	0.56	(0.075)	-	-	659	(174)	217
10/24/75	0.75	(0.100)	-	-	704	(186)	232
1/14/76	3.00	(0.400)	125.0	15.0	136	(36)	45
1/16/76	3.00	(0.400)	119.0	18.0	151	(40)	50
2/4/76	4.50	(0.600)	104.0	14.0	148	(39)	49
3/2/76	6.00	(0.800)	110.0	23.0	151	(40)	50
3/10/76	3.80	(0.500)	132.0	78.0	167	(44)	55
7/15/76	20.00	(2.660)	640.0	67.0	45	(12)	15
7/16/76	27.50	(3.660)	1260.0	184.0	31	(8)	10
7/20/76	31.70	(4.220)	2000.0	240.0	34	(9)	11

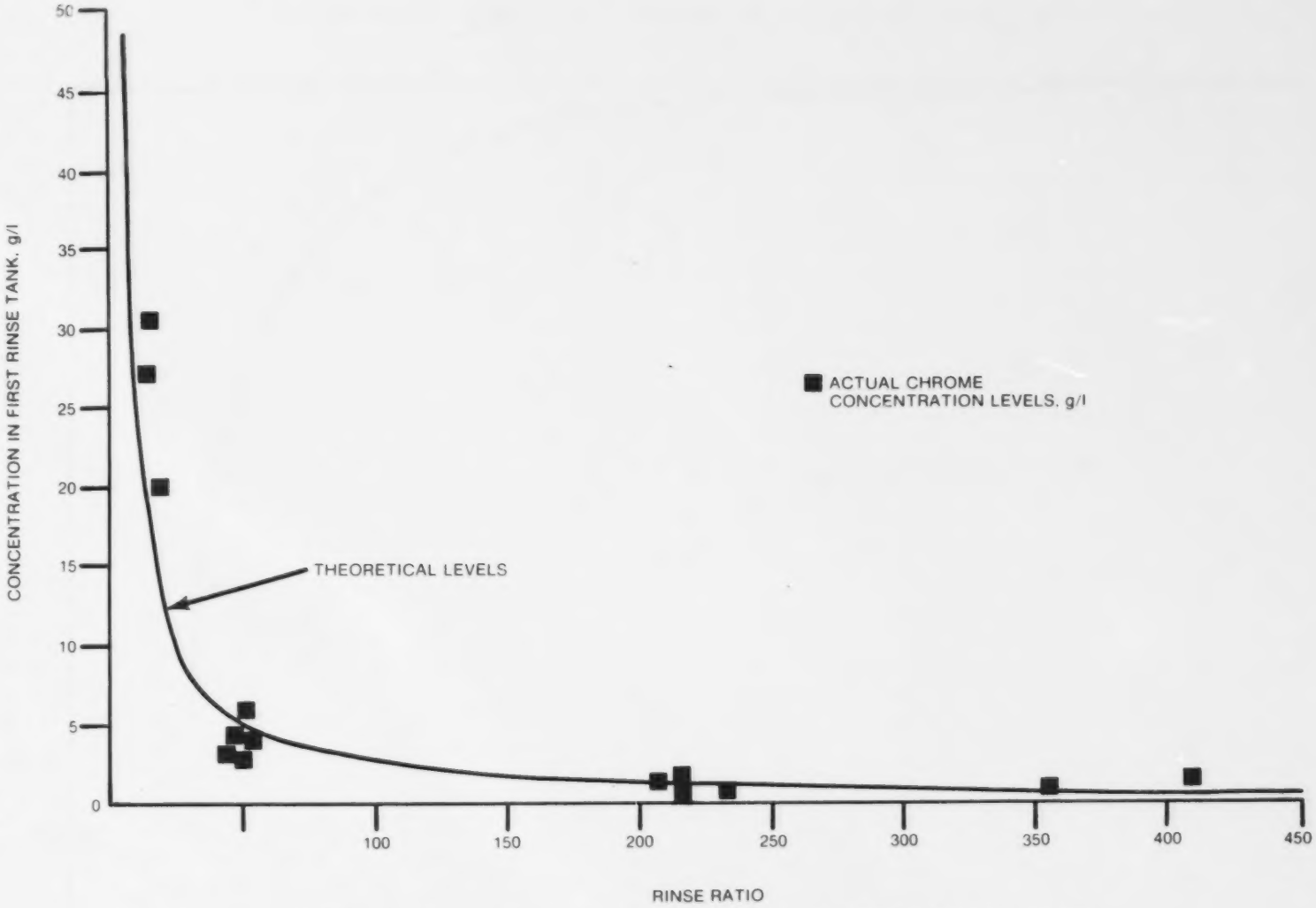

FIGURE 6. CHROME CONCENTRATION IN FIRST RINSE TANK

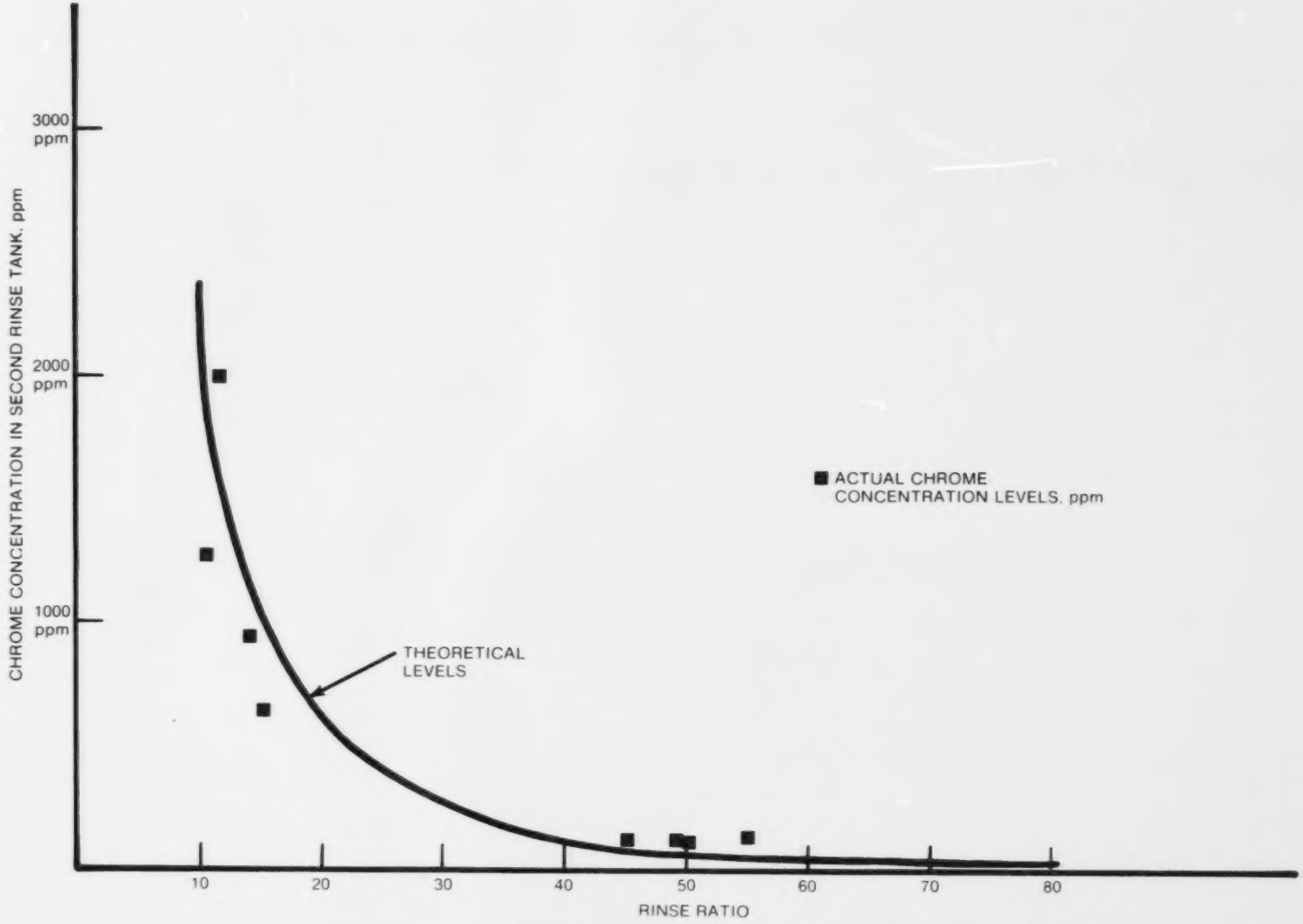

FIGURE 7. CHROME CONCENTRATION IN SECOND RINSE TANK

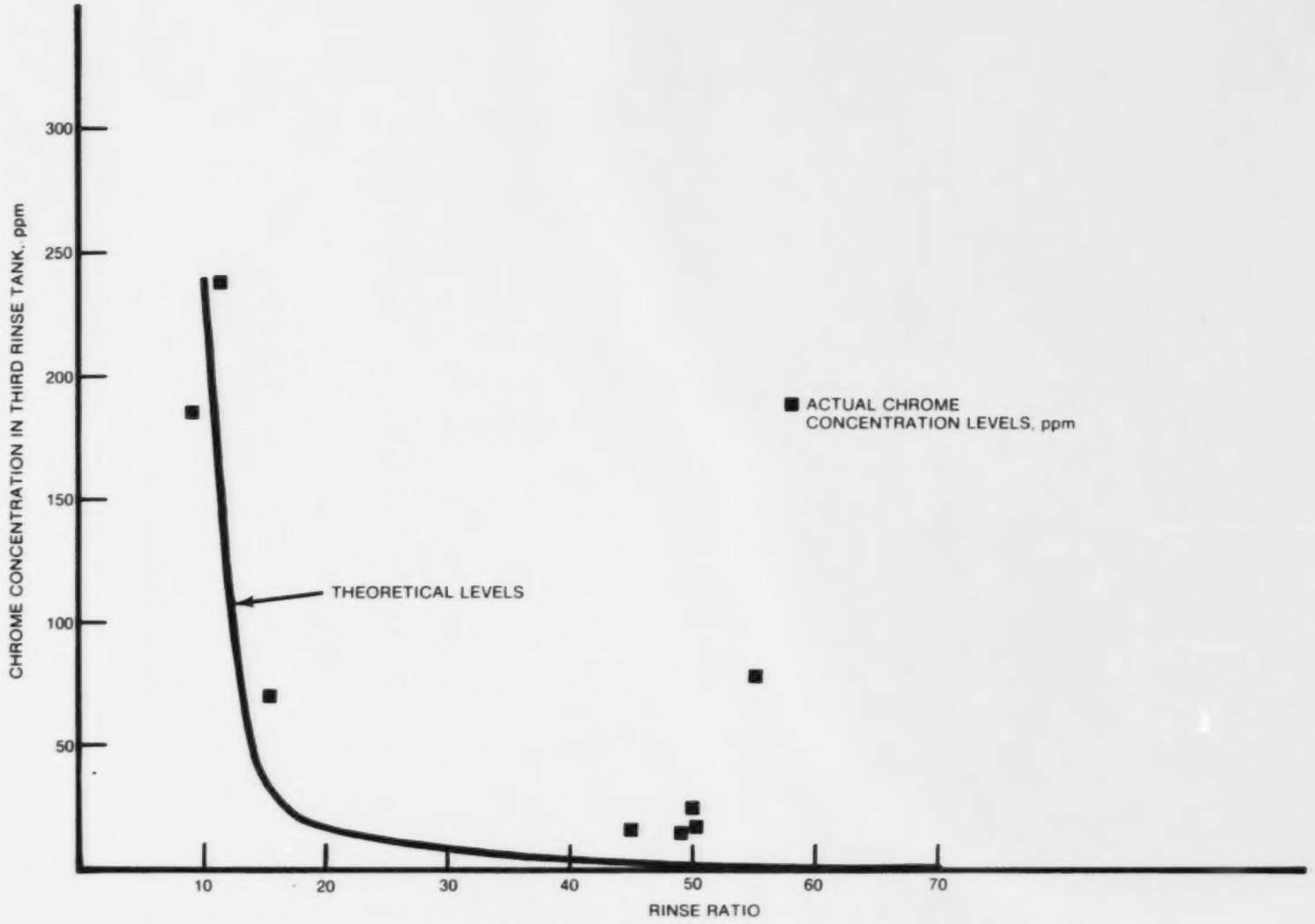

FIGURE 8. CHROME CONCENTRATION IN THIRD RINSE TANK

2. Higher than theoretical values in the third rinse tank at high rinse ratios are probably due to either or both of two factors: Less-than-perfect rinsing conditions; and, at higher flow rates, distilled water returning from the evaporator still containing trace amounts of chrome.

3. If chrome content of less than 10 ppm is desired in the final rinse, the distilled water should be returned to the next-to-last tank and the final rinse should be maintained as a flowing rinse outside the recovery loop.

One important question concerns the effect that low rinse ratios have on the cleanliness of the final product. Discussions with production personnel at Advance Plating revealed that at all times, even with rinse ratios as low as 12, the quality of rinsing was adequate. Throughout the test program, no change in the appearance of the ware due to inadequate rinsing was noticed.

CHROME RECOVERY

A comparison of the bath concentration and the concentration in the third rinse in the system gives the percent of chrome recovered. That is:

$$\% \text{ Recovery} = \frac{(C_o - C_n)}{C_o} \times 100 \quad , \qquad (3)$$

where C_o = plating bath concentration, and C_n = concentration of the last rinse tank in the recovery loop. A theoretical recovery rate of 99.98% is achieved by using a value for C_n from Fig. 8, a recommended rinse ratio of 15 and a bath concentration of 300 grams/liter. Compared to a system without recovery, the evaporator reduced to 0.02% the chromic acid in the effluent from dragout.

As shown earlier, the dragout rate from the plating tank is approximately 2.84 l/hr (0.75 gph) at a bath concentration of 300 grams/liter (40 oz/gal). This gives a recovery rate of 850 grams/hr (1.875 lbs/hr) of chromic acid. This number will be used later when considering the economics of the evaporator's operation.

REDUCTION IN CHROME CONSUMPTION

Part of the data-gathering program involved recording chrome consumption for the plating line before and after recovery system start-up. With this data, the degree to which contaminants leaving the plating line is reduced can be determined.

Table 3 shows the monthly chrome consumption of Advance Plating after recovery began in mid-January 1976. Fig. 9 combines the information from Tables 1 and 3 giving 1975-1976 chrome consumption. Fig. 10 is an extension of Fig. 1 and graphically shows how the consumption was adjusted for changes in production rates.

From the last columns in Tables 1 and 3, the average chrome consumption per rack plated before and after start-up of the recovery system is compared to show an 80% decrease from 20 grams to 4 grams per rack. February consumption was treated as being prior to start-up since the reclaimed chrome was not recycled into the plating bath until March.

Several factors can explain the difference between the 99+% theoretical recovery rate and the 80% actual reduction rate for chrome consumption.

One factor to be considered is the fact that the installation is owned by and under the control of the plating shop. If, at the shop's discretion, the unit is not operated, no recovery takes place.

A second factor is down-time due to equipment failure, which produces a zero recovery rate during the time the equipment is not operating. This factor will be discussed in more detail later.

A third consideration is that this evaporator system was installed such that it could not be operated while the ion exchange unit was being regenerated. Operating the evaporator during this regeneration period, however, would not have any unfavorable effects on the plating bath since cation buildup would have been minimal. It should be noted that this system will be changed to allow simultaneous regeneration and recovery.

And, finally, 10% of the chrome is plated on the ware.

CONTROL OF CONTAMINANTS

The primary function of the cation exchanger was to remove cationic contaminants from the chrome-bearing rinse waters prior to concentration by the evaporator. The ion exchanger was initially sized by measuring the chrome build-up in the first rinse tank over four hours. The tank was first filled with tap water and operated as a still rinse. In determining the contaminant level, it was assumed that contaminant dragout would be proportional to contaminant concentration in the plating bath.

TABLE 3. 1976 CHROME CONSUMPTION-ADVANCE PLATING

Month	Chrome Consumption kg	(lb)	Numbers of Racks Plated	Chrome Consumption Per Rack g	(lb)
January	314	(694)	Not Available	-	
February	314	(694)	19,555	16.4	(0.036)
March	0	(0)	23,273	0.0	(0)
April	91	(200)	22,970	4.0	(0.009)
May	204	(450)	24,432	8.3	(0.018)
June	91	(200)	24,538	3.7	(0.008)
July	91	(200)	18,239	5.0	(0.011)

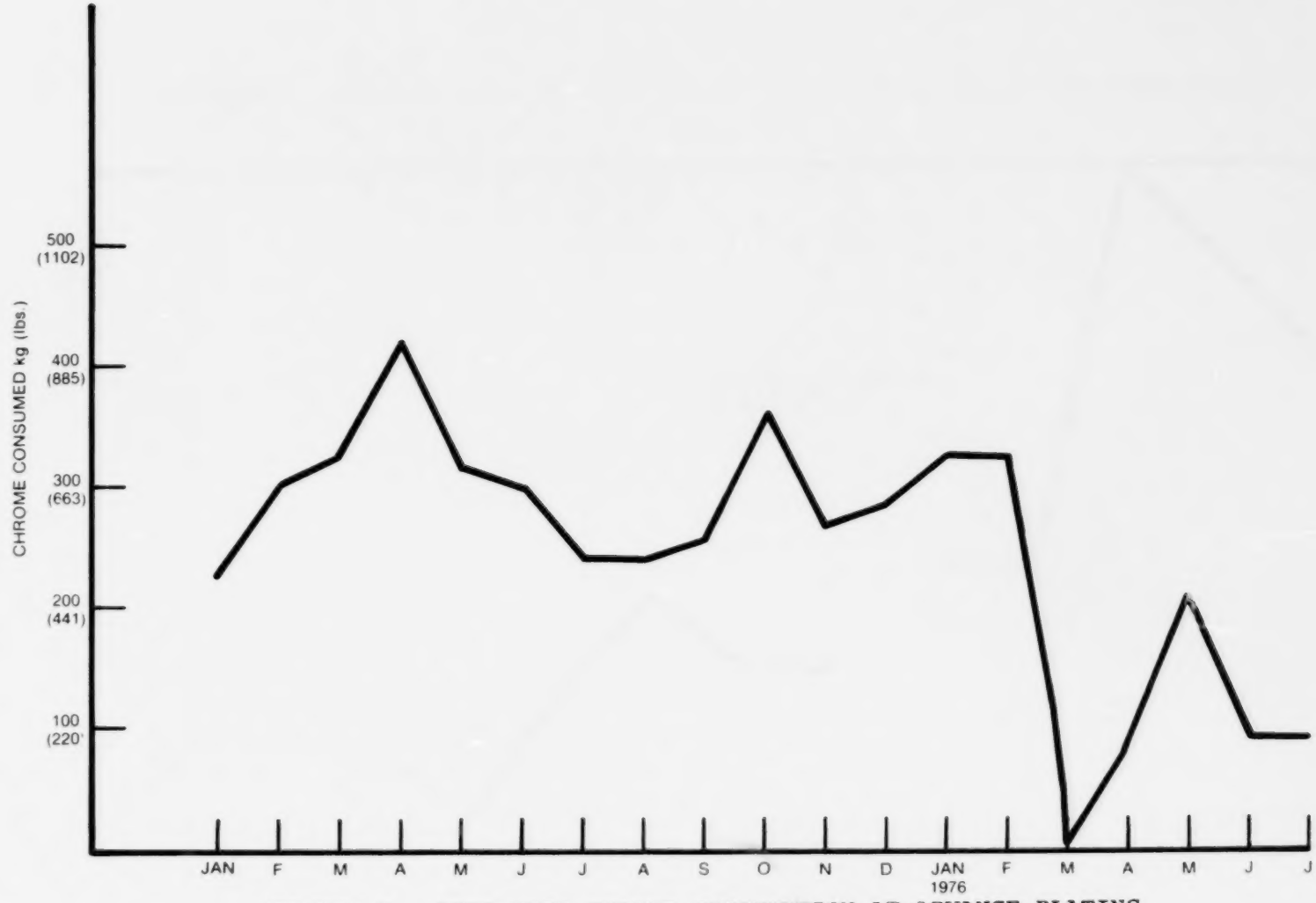

FIGURE 9. 1975-1976 CHROME CONSUMPTION AT ADVANCE PLATING

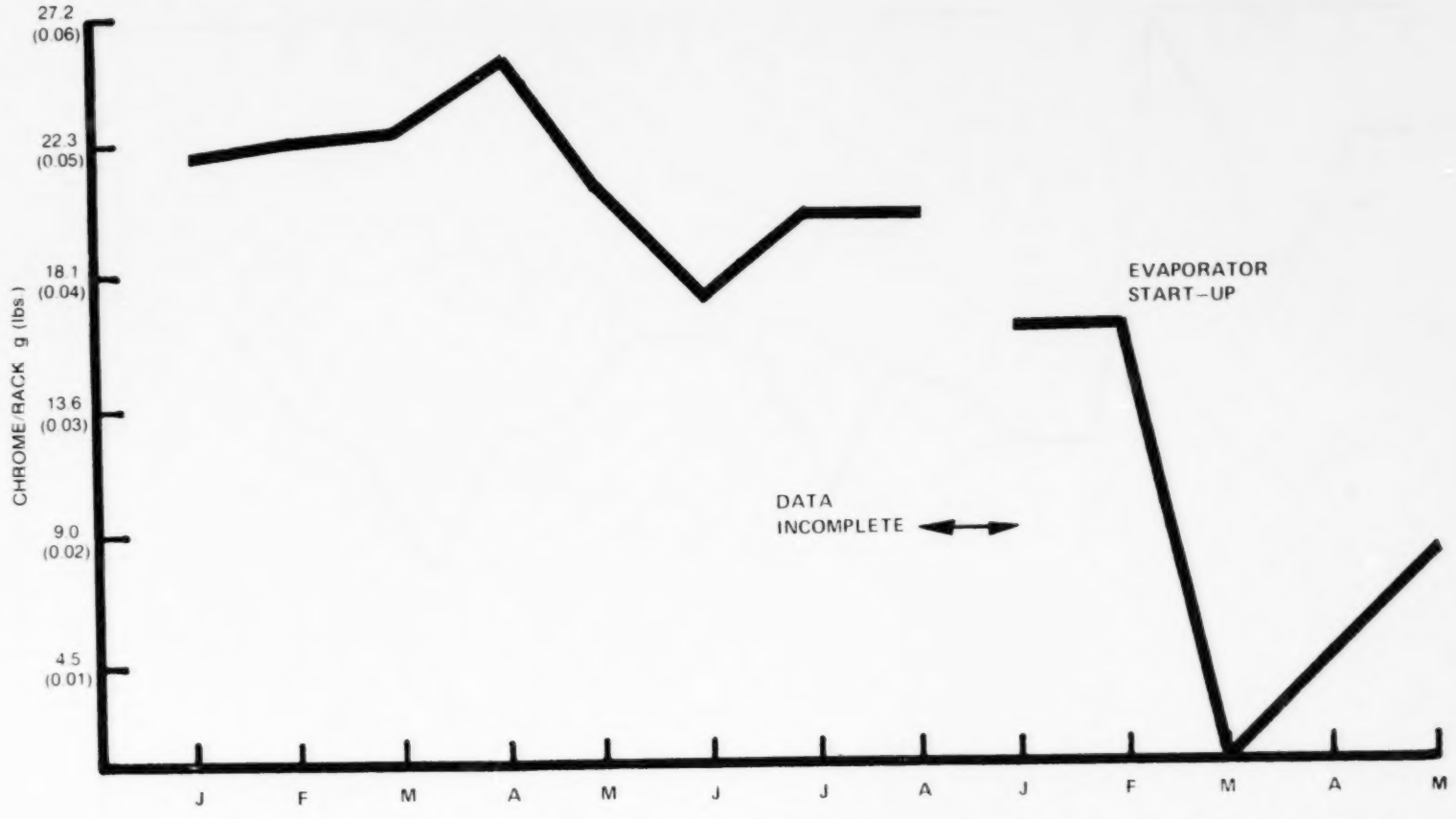

FIGURE 10. 1975-1976 CHROME CONSUMPTION PER RACK PLATED AT ADVANCE PLATING

The earlier presentation of this data showed the dragout rate to be 2.84 l/hr (0.75 gph). Table 4 presents a chemical analysis of the contaminants in the plating bath and the still-rinse water.

Discussion with representatives of Industrial Filter indicate that the cations are absorbed in their ion exchange units at a level of 1.5 lbs. for each cubic foot of resin. This suggested that a four-cubic-foot exchanger would handle the contaminant loading. The eight-cubic-foot unit was chosen for this study in order to provide margin for extra capacity.

Periodically, plating bath and recovered solution samples were sent to an independent laboratory in Cleveland for chemical analysis. Results of these analyses are presented in Table 5 and are discussed in the following section.

SYSTEM IMPACT

Plating Quality

During the first three months of operation, no notable plating quality problems were encountered. In May, a problem with clouding of the ware resulted in a higher than normal reject level. Since rinsing quality had no effect on the appearance of the ware, contamination of the plating bath was suspected.

In mid-June the plating bath was replaced with a similar solution from another plating operation being moved into Advance Plating's shop. This action was taken because the replacement bath was readily available. The replaced plating bath was not examined further, so the actual cause of the ware clouding was never determined. However, some probable causes were studied. Chemical analysis by the bath supplier indicated a less than optimum ratio of active fluoride to total fluoride in the catalyst. This condition may have been caused by a high level of aluminum cations complexing excessive amounts of free fluoride.

Three possible solutions to this problem have been proposed and will be implemented in the near future:

1. Remove more quickly any parts dropped into the plating bath.

2. Artificially increase dragout so that the bath has less dwell time in the plating tank before being cycled through the cation exchanger. This minimizes the effect of dropped parts.

TABLE 4. CHEMICAL ANALYSIS DATED JUNE 19, 1975
SOLUTION CHECKED - PLATING BATH
DRAGOUT RATE - 2.84 LITERS/HOUR

Metal Ion	Content Grams/Liter	Dragged Out Of Plating Bath in 1 Hour gm	oz.
Trivalent Cr	1.1	3.12	0.11
Iron	0.17	0.48	0.017
Copper	0.32	0.91	0.032
Nickel	0.67	1.90	0.067
Zinc	3.7	10.51	0.374
Magnesium	0.038	0.108	0.004
Calcium	0.030	0.085	0.003
Sodium	0.49	1.39	0.049
Tin	0.028	0.080	0.003
Total Contaminants/Hour		18.58	0.66
Contaminant Level After One Week (3 shift/day operation)		2230	79.2 (4.95 lb)

TABLE 5. CHEMICAL ANALYSIS OF PLATING BATH
(All data in grams/liter)

Metal Ion	Before Start-Up	Start +3 Months	Start +4 Months	Recovered Solution
Total Cr	131.00	118.00	119.00	117.00
Trivalent Cr	1.10	0.31	0.20	0.38
Iron	0.17	0.22	0.48	0.97
Copper	0.32	0.37	0.37	0.16
Nickel	0.67	1.90	2.00	0.58
Zinc	3.70	7.00	6.80	2.00
Magnesium	0.038	0.39	0.40	0.19
Calcium	0.030	0.38	0.48	0.50
Sodium	0.49	0.79	0.77	0.93
Tin	0.28	0.084	0.07	0.052
Aluminum	0.11	0.37	0.32	0.16

3. Better programming of cation regeneration.

Plant Operations

In order to describe the effect the recovery system had on plant operations, a session was held at the conclusion of the project with plant personnel at all levels, from equipment operator to president. Comments on the system made during this meeting emphasized several important factors:

Operational

1. Operator averaged 10 minutes per day routinely attending the unit.

2. Operator spent two hours per week regenerating the ion exchange system.

3. No additional people hired; the full operation was handled by existing manpower -- one man.

4. No rinsing problems noted throughout the test program.

5. Manual chromic acid additions were drastically reduced.

6. Discovered that the evaporator drained when plant air was shut off for the weekend - manual valve installed to prevent recurrence.

Routine Maintenance

Other than normal operation of equipment, the system required only minor maintenance.

SYSTEM RELIABILITY

The reliability of the recovery system was determined from the traces on the differential pressure recorder chart. In this data, "availability" was defined as including all periods in which the recovery system was functional, even though it was not actually being run. If the unit failed while operating or if it couldn't be started because of mechanical problems, it was considered as being unavailable or "down". Table 6 details the availability of the equipment.

TABLE 6. RECOVERY SYSTEM AVAILABILITY

Month	Hours Up	Hours Down	% Operational
Jan. 76[1]	192	57[2]	77%
Feb. 76	367	5	99%
Mar. 76	391	13	97%
Apr. 76	309	2	99%
May 76	343	0	100%
June 76	371	14	91%
July 76	261[3]	0	100%
Feb-July Total:	2042	34	98.3%

[1] Start-up mid-January.

[2] Downtime included travel time of an engineer from Corning, New York to Cleveland to observe repair.

[3] Recorders turned off for a portion of the month, yielding a lower total operating time being monitored.

It should be noted that the high downtime figures in January and June directly resulted from Corning's desire to observe first-hand any problems encountered. As a result of this policy, travel time from Corning, New York, to Cleveland significantly increased the total downtime.

No repair took longer than one hour to complete.

COST ANALYSIS

Installation Costs

This demonstration project has proven the validity of the theoretical rinsing equations. With the average dragout at Advance Plating of 2.84 l/h (0.75 gph) an evaporator with a capacity of 45.42 l/h (12 gph) would be suitable. The Model PCR-60 evaporator used at Advance Plating was selected in order to achieve the objectives of the study. The impact upon system cost is shown in Table 7 by comparing the costs of the demonstration unit and one that is properly sized - a Model PCR-20.

Operating Costs

A major objective of this study was to evaluate the economics of the operating evaporative recovery system. This system is economically viable if the system operating costs are less than the savings as measured by

(a) Reduced procurement of new chromic acid,

(b) Reduced procurement of chemicals required to prepare the chromic acid effluent for waste disposal,

(c) Reduced charges for the transportation and landfilling of the sludge, and

(d) The cost of the water previously used in rinsing.

At Advance Plating these savings were:

a. Purchase price ... $.915 per pound at Advance Plating.

b. Neutralization chemicals ... not done at Advance Plating.

TABLE 7. COST COMPARISON

	Demonstration Unit	PCR-20 Cr
Equipment		
Evaporator (PCR-60 Cr)	$ 32,500.00	$ 19,900.00
Tanks	1,647.66	1,647.66
Pumps	753.55	753.55
Cation Exchanger	6,195.00	6,195.00
Piping	2,496.55	2,496.55
Cooling Tower (1)	3,339.27	3,339.27
Miscellaneous	453.13	453.13
	$ 47,385.16	$ 34,785.16
Installation - Labor and Materials		
Site Preparation	$ 257.33	$ 257.33
Plumbing	2,864.07	2,864.07
Electrical	1,228.75	1,228.75
Equipment Erection	268.63	268.63
Miscellaneous	501.99	501.99
	$ 5,120.77	$ 5,120.77
Total Installation Cost		
Equipment	$ 47,385.16	$ 34,785.16
Labor and Materials	5,120.77	5,120.77
	$ 52,505.93	$ 39,905.93

(1) Cooling tower costs were calculated at 20% of total tower installation since only a portion of the water is used for the recovery system.

The above totals do not include those expenses relating only to purchase and installation of monitoring equipment required specifically for this project.

c. Sludging and trucking to landfill ... not done at Advance Plating.

d. Rinse waters saved by recycling ... not evaluated.

The cost to operate the recovery system is made up of the following factors:

a. Utility costs to operate the evaporator: steam, water, electricty.

b. Labor costs to operate the evaporator.

c. Chemical and utility cost to operate the cation exchanger.

d. Labor costs to operate the cation exchanger.

They are discussed below.

Utility and Labor Costs ... Evaporator

Detailed experiments have shown that boiler steam efficiency is 93%. Fig. 11 details the utility and labor costs to operate an evaporator. The electrical consumption was based upon the vacuum pump motor horsepower and the horsepower to recirculate the condenser cooling water through the cooling tower. Cooling tower make-up water rate was 2% of the flow rate through the condenser. All utility charges were those in effect at Advance Plating during the study.

Utility and Labor Costs ... Cation Exchanger

The operation of the cation exchanger was also a major contribuion to operating costs. These charges are shown in Figs. 12 and 13. Figure 14 shows the total operating costs per hour versus the size of the evaporator selected. The larger the evaporator, the greater the cost for steam.

Savings Realized

Table 8 also shows that for each pound of proprietary chromic acid recovered, Advance Plating saves approximately $.50 over the purchase of new chrome. When considering the use of chemical treatment as an alternative adds additional cost, the savings are significantly greater.

Opinions as to the actual cost of chemical destruct are varied and it is beyond the scope of this project to determine them. However, the cost to treat one pound of chromic acid

Figure 11. Costs for evaporating one gallon of water

Utilities

Steam ($1.70/M lbs using 80% conversion from natural gas to steam)

8.33 lbs/gal. x 1.08 (efficiency) x $1.70/M lbs.= $.015/gal.

Electricity (.0314/KWH)

$$6 \text{ HP } (0.745 \text{ KW/HP}) (\$0.0314/\text{KWH}) \left(\frac{1}{60 \text{ gph}}\right) = \$0.003/\text{gal.}$$

Cooling water ($0.56/M gal.)

$$(3000 \text{ gph}) (0.02) (\$0.56/\text{M gal.}) \left(\frac{1}{60 \text{ gph}}\right) = \$0.00056/\text{gal.}$$

Utility Cost to Evaporate One Gallon of Water = $0.0186/gal.

Labor

Start time, stop time and observance of evaporator totalled 10 minutes/day. For a 100-hour week, labor cost was:

$$(10 \text{ minutes/day} \times (5 \text{ day/week}) \times \left(\frac{1}{60} \text{ hour/minutes}\right)$$

$$(\$18.00/\text{hr}) \left(\frac{1}{100} \text{ hours/week}\right) = \$.15/\text{hour}$$

Figure 12. Operation costs of the cation exchanger

Utilities

Electricity

2 HP (0.745 KW/HP) ($0.0314/KWH) = $0.047/hr

Regeneration Chemicals for Each Cycle

H_2SO_4: 122 lbs x $.044/lb = 5.40

Caustic: 104 lbs x .087/lb = 9.00

$14.00

Labor Cost

2 hours for a Regeneration - 2 hrs x $18/hr = $36.00

Figure 13. Frequency of cation regeneration

Cation unit used had 8 cu. ft. resin. This can be loaded to 12#. However, for programming purposes, 8# loading is the regeneration time.

$$\frac{\text{8\# Loading}}{\text{.7 ounce/cations hour}} \times \frac{\text{16 ounces}}{\text{1\#}} = 183 \text{ hours}$$

Cation Regeneration Costs		$/Hour
Labor	$36.00	
Regeneration Chemicals	14.40	
	$40.40	.221
Utilities		.047
Total		$.268/hr

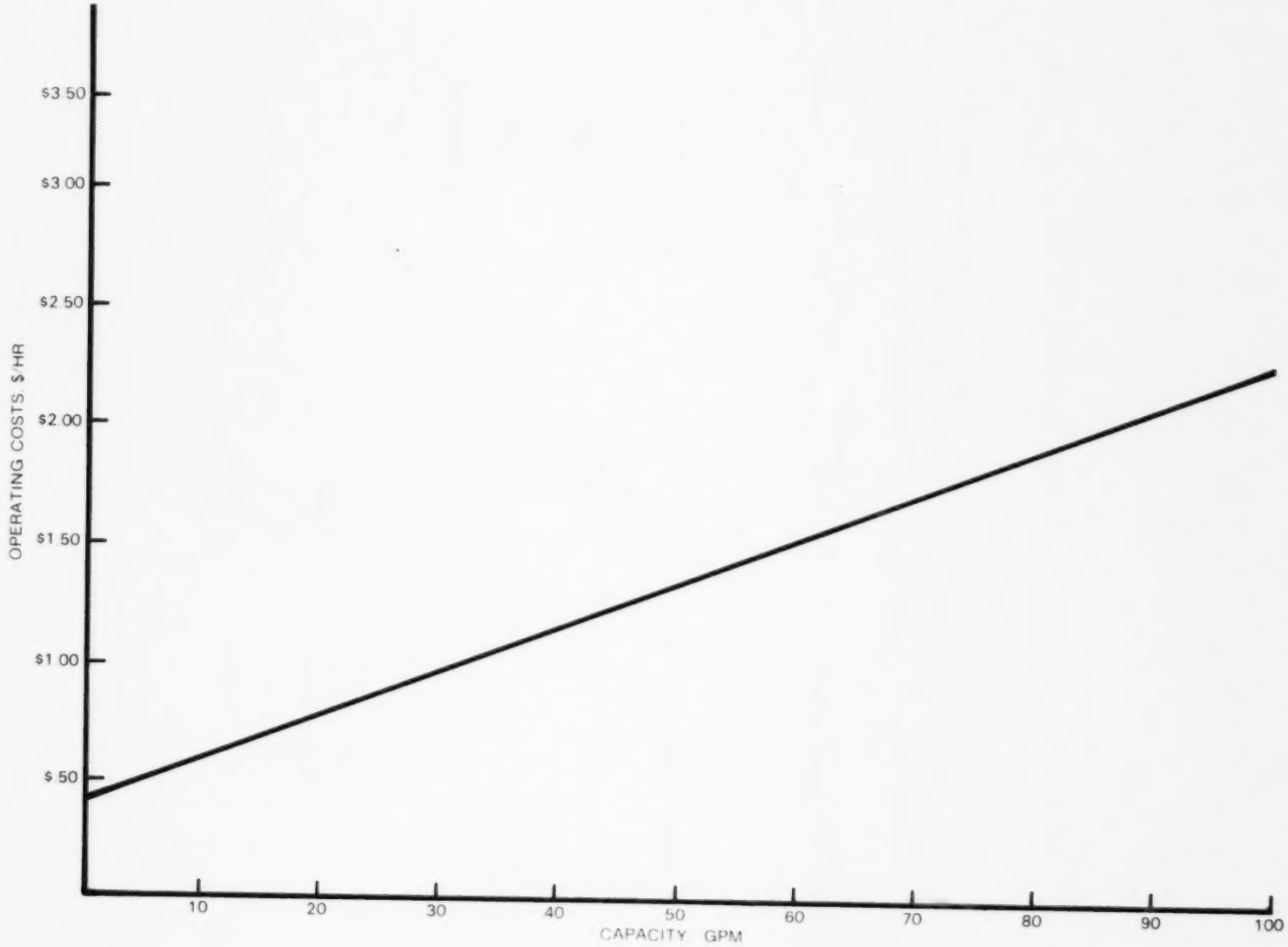

FIGURE 14. HOURLY OPERATING COSTS OF THE SYSTEM EVAPORATOR AND CATION EXCHANGER VERSUS CAPACITY

can be simply added to the out-of-pocket savings detailed in Table 8 for the total savings over a treatment system. For example, assume a destruct cost of $1.00 per pound and a counterflow rinsing system using a 20 GPH evaporator, then the total savings realized per pound of chrome recovered is $1.50.

Estimated Savings in Your Shop

A model to estimate savings for every electroplater is shown in Table 9 using the following assumptions.

1. Utility costs are identical to those at Advance Plating.

2. Evaporator is sized at 15 times the average dragout.

3. Concentration of chromic acid is 300 grams/liter (40 oz/gal).

4. Purchase price of proprietary decorative chrome is $.915/lb.

TABLE 8. SAVINGS BY RECOVERY

Dragout	Gallons/hour	.75
	lb/hour	1.875

Value of recovered chrome @ $.915/lb	$1.72
Reduction of neutralization chemicals	none used
Reduction of sludge trucking charges	none used
Reduction in water usage	not evaluated
Total savings $/Hour	$1.72
Cost to operate a 20 GPH recovery system (Fig. 13) $/Hour	$ .79
Net savings $/Hour	$ .93
or	
Net savings $/# chrome recovered	$ .50

TABLE 9. ANNUAL OUT-OF-POCKET SAVINGS* ($)

DRAGOUT #/HOUR	WITHOUT WASTE TREATMENT 1 SHIFT	2 SHIFTS	3 SHIFTS
1	$ 1160	$ 2320	$ 3480
2	$ 2320	$ 4640	$ 6960
4	$ 4640	$ 9280	$13920
10	$11600	$23200	$34800

WITH WASTE TREATMENT
MULTIPLY ABOVE VALUES BY THESE FACTORS

COST FOR DESTRUCTION	FACTOR
$ .25/lb	1.43
$ .50/lb	1.86
$ .75/lb	2.29
$1.00/lb	2.72

*Rinse Ratio 15:1